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Erosion Studies

on the

Schoharie Watershed, New York

by

Irvin C. Reigner

Northeastern Forest Experiment Station

Ralph W. Marquis, Director
Upper Darby, Pa.

Forest Service, U.S. Dept. of Agriculture

CONTENTS

	Page
INTRODUCTION	1
THE SCHOHARIE PROBLEM	2
SEDIMENTATION SURVEY	3
WATERSHED STUDIES	6
LAND-USE SURVEY	7
SUPPLEMENTARY STUDIES	10
Road banks	10
Stream banks	12
Reservoir shore	12
Volume estimates	13
Erosion caused by logging	15
CONCLUSIONS	16

EROSION STUDIES
on the
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by

Irvin C. Reigner,[1] *forester*

Northeastern Forest Experiment Station
Forest Service, U.S. Dept. Agriculture

WHEN NEW YORK CITY suffered a serious water shortage in 1949-50, some of the reservoirs in its water-supply system were drained almost empty. In some places land that had been covered with water for nearly a hundred years was exposed. This provided an unique opportunity for studying sedimentation and erosion problems in this area.

In cooperation with the Soil Conservation Service and the City of New York, Department of Water Supply, Gas, and Electricity, the Northeastern Forest Experiment Station took part in a study of these reservoirs. This is a report on that study, with special reference to erosion on forest lands in the Schoharie watershed.

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[1] STATIONED AT THE DELAWARE BASIN RESEARCH CENTER, WHICH IS MAINTAINED AT BETHLEHEM, PA., BY THE NORTHEASTERN FOREST EXPERIMENT STATION, IN COOPERATION WITH LEHIGH UNIVERSITY.

THE SCHOHARIE PROBLEM

Reservoir sediment is, of course, the accumulation of material eroded from the land surface of the watershed or from the stream beds. Although the amount of accumulation is not necessarily the amount of material eroded from the watershed during the life of the reservoir (some of the eroded material may not yet have reached the reservoir; some may have passed through it) these sediments are indicative of the degree of erosion in the watershed.

Preliminary examination of the numerous reservoirs in the New York City water-supply system revealed little or no sedimentation in any except Schoharie Reservoir (fig. 1). Schoharie Reservoir, one of the two reservoirs in the Catskill system, is formed back of Gilboa Dam, which was completed in 1926.

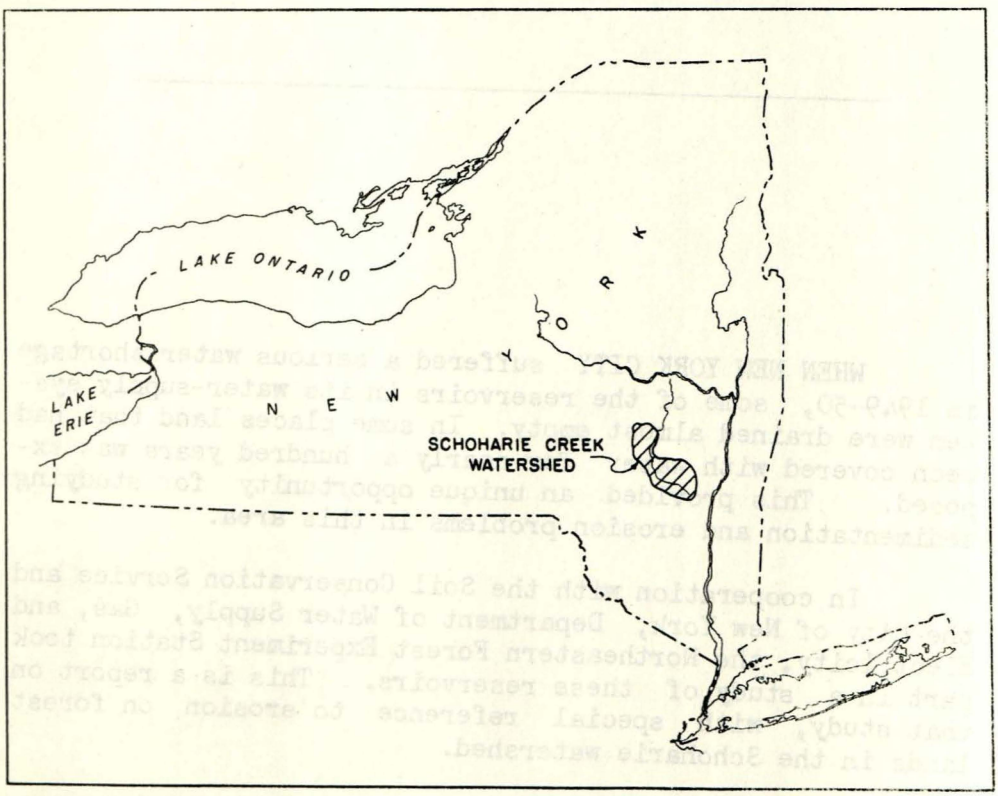

Figure 1.--The location of the Schoharie watershed, one of New York City's sources of water supply.

Waters from Schoharie Creek and its tributaries are caught by Schoharie Reservoir and diverted into Shandaken Aqueduct, which carries them to Esopus Creek. Eventually they reach Ashokan Reservoir where they are stored. The Schoharie intake to the aqueduct is about 3 miles above Gilboa Dam and about 60 feet higher than the lowest elevation in the reservoir. Thus a considerable dead-storage pool is formed in the reservoir.

When Gilboa Dam was being constructed, a temporary dam was built across the reservoir slightly below the intake to divert the flow of Schoharie Creek into the aqueduct, which was completed a year or more before Gilboa Dam was finished. Only a small section of the temporary dam was removed before the reservoir was put into use.

Schoharie reservoir has only a moderate capacity for the size and water yield of its watershed. Thereby it is more than ordinarily susceptible to sedimentation problems. It holds only 14 percent of the total flow of Schoharie Creek for an average year. In comparison, Ashokan Reservoir holds 1.03 times the flow of its drainage area. If the two watersheds were eroding at the same rate, Schoharie Reservoir would fill with sediment more than seven times faster than Ashokan.

Although Schoharie Reservoir is the most recently constructed of the New York City water-supply reservoirs, a rather considerable amount of silt was indicated. During periods of low water, deep deposits were visible in the vicinity of the aqueduct intake. These deposits have been particularly troublesome during low-water periods, partially blocking the channel into the aqueduct. Furthermore, these deposits have raised the level of the dead-storage pool, thus trapping a certain amount of water that otherwise could be used.

SEDIMENTATION SURVEY

To determine the total amount of these sediments, the rate of sedimentation, and an estimate of the useful life of the reservoir, a detailed sedimentation survey was undertaken by the Soil Conservation Service and the Northeastern

Forest Experiment Station in May 1950.[2] Assistance in the form of labor personnel, office space, and motor boats was furnished by the City of New York.

Twenty-three range lines, running across the reservoir and approximately perpendicular to its longitudinal axis, were established. These were more or less equally spaced throughout the length of the reservoir.

Measurements of sediment depths were taken at predetermined intervals along each range line. The sediment-measuring device, a specially made instrument called a "spud," was dropped from the boat at each interval, at which point it penetrated through the sediment and into the original reservoir floor. When pulled up, the spud contained a sample of each 1/10th foot of soil penetrated. From these samples the sediment depth at that particular point was easily measured. Each measurement was related to depth below flow line.

These measurements were plotted as profiles of original reservoir depth and present depth. If it was evident that penetration had not been complete to the original soil, the profile of the original depth was reconstructed from contour maps made before the completion of the reservoir. Finally, specialized formulae were applied to the various measurements to get the desired information.

During the course of the survey it became more and more evident that sediment depths were shallow throughout most of the reservoir. The silt deposits in the vicinity of the aqueduct intake were localized in that area by the old temporary diversion dam. Inadvertantly, a settling pool had been formed; a large portion of the sediment load had been deposited in it.

Final computations confirmed the indications that sedimentation had not been excessive. The original reservoir capacity of 63,821 acre-feet had been reduced to 62,702 acre-feet by 1,119 acre-feet of sediment. Thus, in 24 years, the total capacity was reduced only 1.75 percent or 0.073 percent per year. At this rate the reservoir would not be filled with sediment for some 1,300 years.

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[2] MOORE, WILLIAM R., AND FERRIS, H. JAMES. REPORT ON SEDIMENTATION IN SCHOHARIE RESERVOIR. U.S. SOIL CONSERV. SERV. NORTHEAST. REGION. 21 PP., ILLUS. UPPER DARBY, PA. 1951.

Long before that time, however, the silt level would reach the aqueduct intake, thus making the diversion of water very difficult. Even now, the distribution of sediment has resulted in a much greater loss in usable storage capacity than the above figures indicate.

The usable capacity of the reservoir--the storage area above the dead-storage pool--was originally 57,814 acre-feet. Of the total sediment, 702 acre-feet were deposited in this usable capacity. Part of this has formed an 8-foot bar in front of the aqueduct intake; this bar prevents full drawdown and use of the theoretical usable capacity. The loss due to the bar amounts to 2,746 acre-feet in addition to the aforementioned 702 acre-feet of deposited sediment. The total storage loss, 3,448 acre-feet, is equivalent to nearly 6 percent of the original usable capacity.

Further consideration must be given to the dead-storage pool. Although sediment deposits in it do not result in a loss in usable storage, extreme complications will arise after the dead-storage pool has been filled with sediment. From then on, new sediments will be drawn toward the intake, making removal of stored water very difficult as well as lowering the quality of the water that is drawn from the reservoir.

At the time of the survey, sediment deposits had reduced the original dead-storage capacity 6.94 percent. At this rate, all dead-storage capacity would be lost in about 350 years. If the temporary diversion dam were removed, the rate of sedimentation in the dead-storage pool would no doubt be increased, allowing still less time for efficient operation of the reservoir. It may be possible, of course, to maintain a dead-storage pool indefinitely by flushing out sediments periodically through the blow-off conduit under Gilboa Dam.

Some additional sediment has been discharged along with water leaving the reservoir. Studies of turbidity records of the effluent passing through Shandaken Aqueduct indicate a total of about 112 acre-feet of sediment has been discharged by this means. No records are available of the amount of sediment that may have passed over the spillway during the short periods when the reservoir was overflowing, but it may be assumed to be negligible.

Thus, it has been possible to account for a total of 1,231 acre-feet of sediment having passed into Schoharie

Reservoir (table 1). This figure is also a reliable indication of the amount of material eroded from the watershed of Schoharie Reservoir since the building of the reservoir.

Table 1.--Summary of water capacity and sedimentation of Schoharie Reservoir

Item	Quantity
	Acre-feet
Water capacity	
Original:	
Usable storage	57,814
Dead storage	6,007
Total	63,821
Present:	
Usable storage	57,112
Dead storage	5,590
Total	62,702
Sedimentation	
In usable storage capacity	702
In dead storage capacity	417
Passed through Shandaken Aqueduct	112
Total	1,231

WATERSHED STUDIES

Schoharie watershed, the catchment area for Schoharie Reservoir and the source of this eroded material, is about 200,000 acres in extent (fig. 1). It lies mainly in Greene County in the Catskill Mountains. Very little of the terrain is level; most of it may be classed as steep. Elevations range between 1,000 and 4,000 feet above sea level. The valleys are generally narrow.

The economy of the locality is based on dairy farming; very little area is devoted to crop cultivation. Tourist and recreation trade is second in importance as a source

of revenue to inhabitants of the watershed. Small logging operations are fairly numerous, although much of the forest area is in the Catskill State Park system and is thus reserved from cutting. Industry is negligible.

This, then, is the watershed from which 1,231 acre-feet of soil mantle has eroded within a 24-year period. Assuming that each acre eroded equally, only 0.074 inches of material was removed from the horizontal area of the watershed during the period (1,231 x 12/200,000), or 0.003 inches per year. This amount, while theoretical, indicates that erosion throughout the watershed has not been particularly severe.

But what are the characteristics of the drainage area that influence this erosion?

LAND-USE SURVEY

Concurrently with the sedimentation survey, the Soil Conservation Service made a reconnaissance survey of the land conditions in the watershed. Land use, slope, and soil were classified and related to erosion (table 2). This survey was made by stereoscopic study of aerial photographs. Information taken from existing soil surveys and a general knowledge of the locality aided and supplemented the interpretation.

It was found that about 55 percent of the land is covered with forest, and about 43.5 percent is in grass. Slightly more than 1 percent is plowed in any one year and a few small villages occupy the remaining small area.

Steep slopes predominate on the watershed; 60 percent of the area is on slopes steeper than 20 percent. Less than 5 percent is on land with so little slope that it has no erosion hazard. The remaining 35 percent lies on slopes from 5 to 20 percent.

It is notable that the area of severe erosion is very small. However, a large area, more than 46 percent of the watershed, has been moderately eroded (table 3). Significantly, more than 80 percent of this moderately eroded land is in grass. Forest land, on the other hand, has been

Table 2.--Land use, slope, and areal extent of erosion on Schoharie Watershed

(In percentage of total watershed area, 200,960 acres)

Land use	Slight[1] erosion	Moderate[2] erosion	Severe[3] erosion
LEVEL LAND			
Forest	0.87	0	0
Grass	3.22	0	0
Cultivated	0.40	0	0
Urban	0.14	0	0
Total	4.63	0	0
SLOPING LAND			
Forest	7.66	3.39	0
Grass	1.72	21.56	0.14
Cultivated	0.08	0.47	0
Urban	0	.13	0
Total	9.46	25.55	0.14
STEEP LAND			
Forest	38.06	4.92	0.19
Grass	1.22	15.67	0.06
Cultivated	0.003	0.08	0
Urban	0	0.006	0.005
Total	39.28	20.68	0.25

[1] Slight erosion: Little or none of the surface soil has been lost.

[2] Moderate erosion: 2 to 6 inches of the original 8 to 10 inches of surface soil has been lost.

[3] Severe erosion: All or nearly all of the original 8 to 10 inches of surface soil has been lost and in some places part of the subsoil has been lost.

Table 3.--Land use in relation to degree of erosion, in percent of total watershed area

Land use	Slight erosion	Moderate erosion	Severe erosion
Forest	46.59	8.31	0.19
Grass	6.16	37.23	0.20
Cultivated	0.48	0.55	0.0
Urban	0.14	0.14	0.0
Total	53.37	46.23	0.39

eroded much less (fig. 2)--even though a much greater proportion of it is on the steeper slopes (table 4). Only 18 percent of the moderately eroded land is in forest cover.

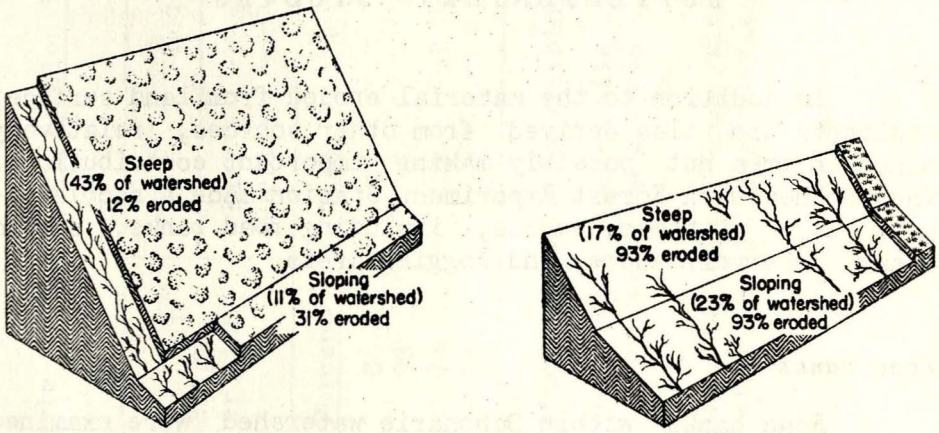

Figure 2.--A graphic comparison of forest land and open land in the Schoharie watershed, and the extent of erosion on each.

A computation of soil loss from sloping land indicates that about 1,000 acre-inches of soil are lost annually, amounting to about 2,000 acre-feet for the 24-year period.

This is somewhat higher than the previous estimate but the difference is not so great as to invalidate either figure.

Table 4.--Land use in relation to slope, in percent of total watershed area

Land use	Level	Sloping	Steep
Forest	0.87	11.05	43.17
Grass	3.22	23.42	16.95
Cultivated	0.40	0.55	0.08
Urban	0.14	0.13	0.01
Total	4.63	35.15	60.21

SUPPLEMENTARY STUDIES

In addition to the material eroded from land surface, sediments are also derived from other sources, relatively minor in area but possibly making important contributions. The Northeastern Forest Experiment Station made a supplementary study of these sources, including road banks, stream banks, reservoir shore, and logging areas.

Road Banks

Road banks within Schoharie watershed were examined for eroding conditions by a field survey of randomly selected road segments.

Base maps of the area show four classes of roads: (1) hard-surface, heavy duty roads; (2) secondary, hard-surface, all-weather roads; (3) loose-surface, graded, dry-weather roads; and (4) dirt roads. The total linear extent of each class of road within the watershed boundary was scaled from the base maps. Ten sample road sections, 1/2 mile in length, were located on the base maps for each road class. Sample location was determined by random methods.

Table 5.--Road-bank erosion in Schoharie Watershed

Road class	Slight[1] erosion	Moderate[2] erosion				Severe[3] erosion
		Bank surface	Road surface	Shoulder surface	Total	
	Percent	Acres	Acres	Acres	Percent	Percent
1. (71.56 mi.)	86	11	--	1	14	--
2. (103.11 mi.)	98	3	--	--	2	--
3. (144.88 mi.)	73	1	44	--	27	--
4. (107.61 mi.)	58	3	41	--	40	[4] 2

[1] Slight erosion: Little or no visible evidence of erosion.

[2] Moderate erosion: On slopes with little or no vegetative cover; soil erosible with little consolidated material; some material deposited at bottom of banks or in culverts.

[3] Severe erosion: On steep slopes with no vegetative cover; erosible soil, no unconsolidated material; gullies developed with considerable deposition at bottom of slope.

[4] Affects 3 acres of road surface.

Each sample was inspected. Five 50-foot linear strips of roadway, equally spaced within the ½-mile sample, were closely examined for erosion. Areas of eroding surface within the 50-foot strip were measured. From these samples, it was possible to estimate the total amount of eroding surface associated with each class of road within the watershed (table 5).

Stream Banks

Stream banks within Schoharie watershed were examined for erosion in a similar manner. Streams were classed in three groups and the total linear distance within each group was determined.

Class 1 stream was Schoharie Creek from the reservoir to the point at which it lost its main stream character among smaller tributaries. Class 2 streams included the larger tributaries, Manor Kill, Batavia Kill, East Kill, and West Kill, from Schoharie Creek to their respective headwaters. Class 3 streams included all small tributaries and subtributaries. Five 1/4-mile sample stretches were randomly located on the base maps for each stream class. Field examination was made on five 50-foot linear strips spaced equally within the 1/4-mile sample. Eroding surface was determined and estimates were computed on a watershed basis. Table 6 summarizes stream-bank erosion.

Reservoir Shore

From cursory observations made during the sedimentation survey it was apparent that the reservoir shore lines were eroding to a considerable degree and contributing a part of the sediments found below the flow line. A large proportion of the shore area is very steep; much of it is undercut by wave action, which washes away the fine material. Many of the steep banks are slumping; free rocks are exposed above and below the flow line, showing that the original soil has been washed away. In addition, there are a number of slide areas that reach high up the steep slopes.

In order to determine the areal extent of eroding land surface (land surface of unconsolidated material not covered with vegetation) a trip around the reservoir shore was made by boat. Each linear section of eroding bank above the flow line was plotted on a map of the reservoir, along

Table 6.--Stream-bank erosion in Schoharie Watershed

Stream class	Slight[1] erosion	Moderate[2] erosion	
	Percent	Acres of bank surface	Percent
1. (22.70 mi.)	92	2.5	8
2. (53.84 mi.)	88	7.3	12
3. (331.90 mi.)	98	3.2	2

[1] Slight erosion: Some evidence of washing.

[2] Moderate erosion: On steep slopes, vertical or undercut banks with little or no vegetative cover; soil erosible with little consolidated material; small gullies or other evidence of washing present. No severe erosion was found.

with an estimate of the average height of each section. Each section was also classified as to the severity of erosion on it--either moderate or severe.

Following the field examination, each section was scaled from the map for linear distance. Surface area of each section was then determined, using the estimate of average bank height. Table 7 summarizes extent and area of eroding banks.

Volume Estimates

Rates of soil loss from road banks, stream banks, and the reservoir shore were determined by the Soil Conservation Service with the use of a nomograph. The nomograph makes it possible to take a known rate of erosion for a given soil type; apply to it such variables as slope, slope length, cover, and rainfall; and read off a new rate of erosion as affected by the specific conditions encountered on Schoharie watershed.

The rates determined were applied to the acreage figures in tables 5, 6, and 7. Estimated volumes of potential

sediment production from these sources are listed in table 8.

Table 7.--Reservoir-shore erosion in Schoharie Watershed[1]

(Total shore length: 14.42 miles)

Extent of erosion	Moderate[2] erosion	Severe[3] erosion
Linear extent- - - - - - feet..	17,080	2,900
- - - - - - miles..	3.24	0.54
Percent of total shore length..	22.5	3.7
Areal extent - - -square feet..	161,200	85,945
- - - - - -acres..	3.70	1.97

[1] All eroding areas were undercut, vertical, or steeply sloping.

[2] Moderate erosion: Little or no vegetative cover; unconsolidated material; small gullies or undercutting in evidence.

[3] Severe erosion: No vegetative material; unconsolidated material; sags, slides, and numerous gullies noticeable.

Table 8.--Estimated volumes of eroded material

Source	Volume per year	Volume in 24 years	Percent of total sediment
	Acre-feet	Acre-feet	Percent
Road banks	0.78	18.7	1.5
Stream banks	1.90	45.6	3.7
Reservoir shore	.30	7.2	.6

Erosion Caused by Logging

During the course of the road-bank and stream-bank studies, several logging operations were encountered. Logging operations are fairly numerous in the watershed. Some of them, particularly those on the steeper slopes, are a definite cause of accelerated erosion.

No attempt will be made here to estimate the importance of logging as a contributing factor to erosion and sedimentation. However, the following comments may be useful for further consideration.

Forest stands in the area are generally all-aged. Selective logging with a rather light cut per acre is the general practice. Thus, there is little erosion due to the removal of the vegetative cover.

Horse-logging is found about as frequently as tractor-logging; horses are used on the smaller jobs, tractors on the fewer large operations. Skid trails, usually running down the slope, are the main source of eroded material. Skid trails resulting from horse-logging appear to be less serious than those on which tractors were used.

Most of the operations visited did not seem to represent serious sources of eroded material. However, one job was encountered that presented an outstanding example of the damage sometimes caused by logging.

The site was on a steep mountainside and covered a large area; it had been logged with a light cut per acre. Skidding was done during the preceding winter and spring by tractor, on skid trails generally running perpendicular to the contours. No attempt was made to avoid watercourses. As a result, flowing water got into the tractor ruts. Erosion was accelerated by the running water until the ruts are now 3 to 4 feet deep in places. These eroded ruts appear to have taken the place of the original stream channels. Thus, a source of erosion and sedimentation has been developed that may take a number of years to be corrected by nature, and, in addition, it is likely that the water relations for this area have been altered.

CONCLUSIONS

These studies indicate that erosion is not now a serious problem in the Schoharie watershed, and that sedimentation in Schoharie Reservoir is not serious except at the intake to Shandaken Aqueduct.

However, studies of land use and erosion in the watershed indicate that these problems may become worse, because of the inherent erosibility of the soils in the area.

The immediate problem of sediment in the reservoir could probably be met with engineering measures such as removal of the old diversion dam and, possibly, dredging. But these would contribute nothing toward solution of the basic problem. The basic problem is to keep sediment out of the reservoir by arresting soil erosion at its source.

The small capacity of Schoharie Reservoir in relation to the size of the watershed puts another prong on the problem: the need to improve the water-holding capacity of the watershed's soils and thus to regulate stream flow. Regulated stream flow would mean a better flow of water in dry periods and less water wasted in quick runoff that spills over the dam.

These problems suggest that some sort of land-management program should be considered for improving the effectiveness of the Schoharie watershed for producing and storing water. Of course this study was too cursory to justify any detailed recommendations. However, intensive studies and land-management programs on other watersheds, made by the Department of Agriculture in its flood-control work, indicate the kind of measures that should be considered for the Schoharie watershed.

Better grazing practices would apparently do much to prevent erosion. More than 43 percent of the Schoharie watershed is in grass land, and about 86 percent of this grass land is eroding, moderately or worse. This means that most of the grass land is overgrazed or is not suitable for grazing at all. On the gently sloping lands, better pasture control, that is, lighter grazing, would help to reduce erosion. Much of the steep land should not be grazed at all; it is poor pasture at best and could be put to better use as forest land.

Fencing of woodlands adjacent to pastures is another measure that should be considered. Livestock compact the soil, destroy humus, and damage young trees. Grazing thus impairs the ability of forest soils to store water.

Eroding road banks could be stabilized by planting grasses and shrubs. Stabilization of the reservoir shores by similar methods would reduce the accumulation of plant debris in the reservoir. Engineering structures could be used to stabilize certain undercut stream banks. Unpaved roads could be protected from erosion by better drainage systems or by paving.

A land-use program for the Schoharie watershed, containing these and related measures, could be planned only after thorough study of the watershed and its problems. Some sort of land-use program seems to be needed, not only to prevent accumulation of sediment in the reservoir, but to regulate the flow of water into it so that it has more water in dry periods and wastes less as spill in wet periods.

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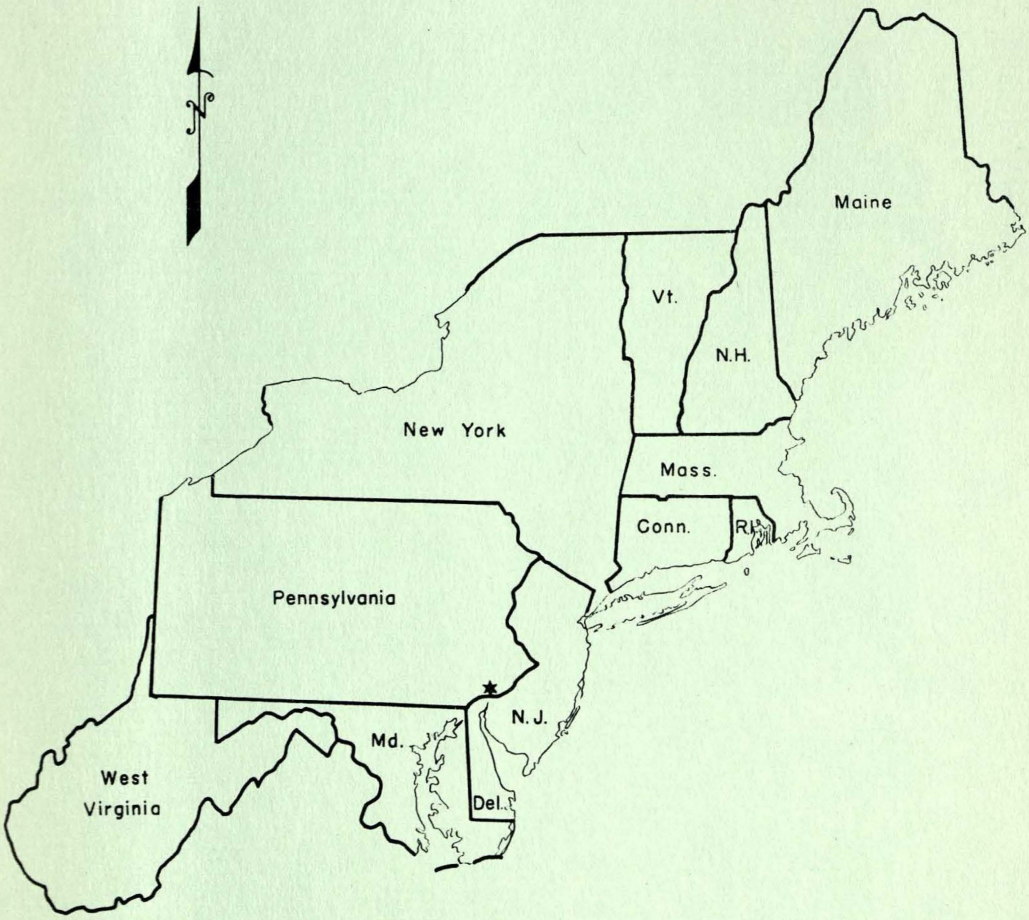

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